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ISO RECOMMENDATION
R 1143

ROTATING BAR BENDING FATIGUE TESTING

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BRIEF HISTORY

The ISO Recommendation R 1143, *Rotating bar bending fatigue testing*, was drawn up by Technical Committee ISO/TC 17, *Steel*, the Secretariat of which is held by the British Standards Institution (BSI).

Work on this question led to the adoption of a Draft ISO Recommendation.

In June 1968, this Draft ISO Recommendation (No. 1350) was circulated to all the ISO Member Bodies for enquiry. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Australia	Italy	Spain
Brazil	Japan	Sweden
Canada	Korea, Rep. of	Switzerland
Czechoslovakia	Netherlands	Thailand
Denmark	Norway	Turkey
Finland	Peru	U.A.R.
Germany	Poland	United Kingdom
Hungary	Portugal	U.S.A.
India	Romania	U.S.S.R.
Israel	South Africa, Rep. of	

Two Member Bodies opposed the approval of the Draft :

Belgium
France

The Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in November 1969, to accept it as an ISO RECOMMENDATION.

ISO Recommendation R 1143 November 1969

ROTATING BAR BENDING FATIGUE TESTING

1. SCOPE

This ISO Recommendation gives the conditions for carrying out rotating bar bending fatigue tests on test pieces having a nominal diameter between 5 mm (0.2 in) and 12.5 mm (0.5 in) without deliberately introduced stress concentrations. The tests are carried out at room temperature, in air, the test piece being rotated.

Results of fatigue tests may be affected by atmospheric conditions and where controlled conditions are required, clause 2.1 of ISO Recommendation R 554, *Standard atmospheres for conditioning and/or testing – Standard reference atmosphere – Specifications*, applies.

2. OBJECT OF TEST

Tests are made to determine fatigue properties such as the *S/N* curve described in ISO Recommendation R 373, *General principles of fatigue testing of metals.*

3. PRINCIPLE OF TEST

Nominally identical test pieces are used, each being rotated and subjected to a bending moment. The forces giving rise to the bending moment do not rotate. The test piece may be mounted as a cantilever, with single-point or two-point loading, or as a beam, with four-point loading. The test is continued until the test piece fails or until a pre-determined number of stress cycles has been exceeded. (See section 10.)

NOTE. – For definitions of failure see ISO Recommendation R 373.

4. SYMBOLS AND DEFINITIONS

In this ISO Recommendation the following symbols are used :

Symbols	Definitions
D	The diameter of the gripped or loaded end of the test piece.
d	The diameter of the test piece where the stress is a maximum.
r	Radius* at the ends of the test section which starts the transition from the test diameter d.

Further symbols and definitions relating to fatigue testing are given in ISO Recommendation R 373.

* This radius need not be a true arc of a circle over the whole of the length between the end of the test section and the start of the enlarged ends for the test pieces shown in Figures 1, 4 and 5.

5. SHAPE AND SIZE OF TEST PIECE

5.1 Forms of test section

The test section may be

(*a*) cylindrical, with tangentially blending fillets at one or both ends (see Figures 1, 4 and 5);

(*b*) tapered (see Figure 2);

(*c*) toroidal (see Figures 3, 6 and 7).

In each case the test section should be of circular cross-section.

The form of test section may be dependent on the type of loading to be employed. While cylindrical or toroidal test pieces may be loaded as beams, or as cantilevers with either single-point or two-point loading, the tapered form of test piece is used only as a cantilever with single-point loading. Figures 1 to 7 show, in schematic form, the bending moment and nominal stress diagrams for the various practical cases.

The volumes of material subjected to high stresses are not the same for different forms of test piece, and they may not necessarily give identical results. The test in which the largest volume of material is highly stressed is preferred.

Experience shows that, for threaded test pieces of certain material, a ratio of at least 3 : 1 between the cross-sectional areas of the test portion and the threaded section is desirable.

NOTE. – In tests on certain materials a combination of high stress and high speed may cause excessive heating of the test piece. This effect may be reduced by subjecting a smaller volume of the material to the specified stress. If the test piece is cooled, the medium should be such that it does not react with the material of the test piece.

5.2 Diameter of test pieces

All the test pieces employed for a fatigue determination should have the same nominal diameter, $d \pm 0.05$ mm (0.002 in).

The nominal value of the diameter, d, should be between 5 mm (0.2 in) and 12.5 mm (0.5 in). The recommended values of d are 6 mm (0.25 in), 7.5 mm (0.3 in), and 9.5 mm (0.375 in).

For the purpose of calculating the load to be applied to obtain the required stress, the actual minimum diameter of each test piece should be measured to an accuracy of 0.01 mm (0.0005 in). Care should be taken during the measurement of the test piece prior to testing to ensure that the surface is not damaged.

On cylindrical test pieces subject to constant bending moment (see Figures 4 and 5) the parallel test section should be parallel within 0.025 mm (0.001 in). For other forms of cylindrical test pieces (see Figure 1) the parallel test section should be parallel within 0.05 mm (0.002 in). The transition fillets at the ends of the test section should have a radius not less than $3d$. For toroidal test pieces, the section formed by the continuous radius should have a radius not less than $5d$.

6. PREPARATION OF TEST PIECE

6.1 Method of machining

It is necessary to ensure than any cutting or machining operation required, either to rough the test piece out from a blank or to machine it to size, does not alter the metallurgical structure or properties of the test piece. All cuts taken in machining should be such as to minimize work-hardening of the surface of the test piece. Grinding may be used particularly in finishing to size test pieces of the harder steels, but an adequate supply of coolant should be ensured so as to avoid undue heating of the surface. (See clause 4.2 of ISO Recommendation R 373.)

Throughout any machining or grinding procedures, the tool or cutter sharpness and setting, the conditions of the wheel and the grinding machine and speeds and feeds, should conform with good workshop practice for the material commensurate with the requirements of clauses 6.2, 6.3 and 6.4.

6.2 Turning

It is recommended that the following procedures should be adopted :

6.2.1 In rough turning the test piece from a diameter $x + 5$ mm ($x + 0.2$ in) (x will generally be the diameter, d, plus a suitable allowance for surface finishing) to $x + 0.5$ mm ($x + 0.02$ in), a succession of cuts of decreasing depth should be made, the recommended depths of cuts being as follows :

1.25 mm (0.05 in)
0.75 mm (0.03 in)
0.25 mm (0.01 in)

6.2.2 From a diameter of $x + 0.5$ mm ($x + 0.02$ in) to x, a further succession of cuts of decreasing depth should be made, the recommended depths of these cuts being as follows :

0.125 mm (0.005 in)
0.075 mm (0.003 in)
0.05 mm (0.002 in)

For these finishing cuts, a feed not exceeding 0.06 mm (0.0025 in) per revolution should be used.

6.3 Grinding

For test pieces in material which cannot be readily turned, it is recommended that the finishing operations are carried out by grinding. Where the strength properties of the material are developed in heat treatment, this heat treatment may be carried out after rough turning to a diameter of $x + 0.5$ mm ($x + 0.02$ in).

The test piece should then be ground to size. A succession of cuts of decreasing depth should be made, the recommended values being as follows :

- 0.030 mm (0.0012 in) depth of cut to 0.1 mm (0.004 in) oversize;
- 0.005 mm (0.0002 in) depth of cut to 0.025 mm (0.001 in) oversize;
- 0.0025 mm (0.0001 in) depth of cut to size.

6.4 Surface finishing

When the test piece has been machined or ground to diameter x, it should be polished either by hand or by machine, using successively finer grades of abrasive papers or cloths. The polishing should generally be in the longitudinal direction, although intermediate stages may be done in any direction to ensure that longitudinal scratches made by the coarser grades of abrasive papers or cloths are removed.

The polishing sequences employed should be such that the finished test section has a surface texture of at least 0.025 microns (centre-line average). It will usually be found satisfactory to arrange the sequence of polishing so that the last paper used is 600 grade waterproof silicon carbide paper.

6.5 Storage prior to testing

If there is an interval between final preparation and testing of the test pieces, they should be examined by appropriate means to ensure that no deterioration of the surface has taken place during the storage period. If there is any deterioration the test piece should be re-polished to remove any surface defects, e.g. corrosion pits.

NOTE. – The procedures given in clauses 6.2, 6.3 and 6.4 represent standard practice for a wide range of materials. It should not be inferred that they are wholly applicable to all materials and to all heat-treated conditions of these materials. For example, the allowance of 0.5 mm (0.02 in) on diameter x, for heat treatment prior to final grinding to size, may not be adequate. The purpose of this allowance is to permit the removal of surface phenomena associated with the heat treatment procedure, such as decarburization, distortion, etc; the allowance used in practice should be sufficient to ensure the complete removal of any features associated with such effects.

Some fatigue investigations may be undertaken to study the behaviour of material with particular surface finishes (e.g. rough machined, fine machined or in the "as received" condition) in which case special conditions would apply.

7. MOUNTING OF TEST PIECE

Each test piece should be mounted in the testing machine in such a manner that stresses at the test section other than those imposed by the applied load are avoided.

If the bearings transmitting the load are secured to the test piece by means of split collets, in certain cases it may be desirable for these to be positioned and fully tightened before the test piece is mounted in the testing machine, in order to prevent an initial torsional strain being imparted. A similar practice may be necessary if the method of securing is by means of an interference fit.

To avoid vibration during the test, co-axiality of the test piece and the driving shaft of the testing machine should be maintained within close limits. Permissible tolerances are ± 0.025 mm (± 0.001 in) at the chuck end and ± 0.013 mm (± 0.0005 in) at the free end – if there is one – for single-point and some types of two-point loading testing machines. For other types of rotating bending fatigue testing machines, the tolerance on eccentricity measured at two places along the actual test section is ± 0.013 mm (± 0.0005 in). The required degree of co-axiality should be established before applying any load.

NOTE. – The recommendations of the test machine manufacturer should be followed when mounting test pieces in the machine.

8. SPEED OF TESTING

It is recommended that tests are carried out within the speed range 1000 to 9000 cycles per minute. Speeds which cause whirling of the test piece should be avoided.

9. APPLICATION OF LOAD

The general procedure for attaining full-load running conditions should be the same for each test piece. The testing machine should be switched on and the desired speed attained before application of load is commenced. The load should then be applied incrementally or continuously until the required value is attained without shock and as quickly as is convenient. Small adjustments in operating speed can then be made if a particular frequency is required.

The accuracy of the applied bending moment should be 1 %.

10. ENDURANCES

The predetermined number of cycles at which a test is discontinued will generally depend on the material being tested. The *S/N* curve for certain materials shows a distinct change in slope in a given number of cycles such that the latter part of the curve is parallel to the horizontal axis. With other materials the shape of the *S/N* curve may be a continuous curve which will eventually become asymptotic with the horizontal axis. Where *S/N* curves of the first type are experienced, it is recommended that the endurance to be used as a basis for the determination be 10^7 cycles and, for the second type, 10^8 cycles.

11. TEST REPORT

In reporting fatigue data, the test conditions should be clearly defined and the test report should include details of the following :

11.1 The material tested and its metallurgical characteristics. Reference can usually be made to the appropriate ISO Recommendation to which the material was produced.

11.2 The method of stressing and the type of machine used. When calibration of the testing machine does not comply with the appropriate part of this ISO Recommendation, the method used should be indicated.

11.3 The type, dimensions and surface condition of the test piece and the points of load application.

11.4 The frequency of the stress cycles.

11.5 When practicable, the temperature of the test piece, if this is significantly higher than that of the test environment.

11.6 The range of relative humidity if this is outside the range of 50 to 70 %. The range of relative humidity should be measured every day throughout the duration of the test.

11.7 The criterion of the end of the test, say its duration (e.g. 2×10^6), or complete failure of the test piece, or some other criterion (see Note 1).

11.8 Any deviations from the required conditions during the test.

11.9 Thermal treatment, if any, given to the test piece.

NOTES

1. In the majority of fatigue determinations the criterion of failure is either the occurrence of a visible fatigue crack or complete fracture. It should be noted, however, that in particular applications other criteria, for example, plastic deformation of the test piece or rate of crack propagation, may be adopted to determine the end of the test.

2. Test results may be presented graphically. Appropriate forms of presentation are illustrated in ISO Recommendation R 373.

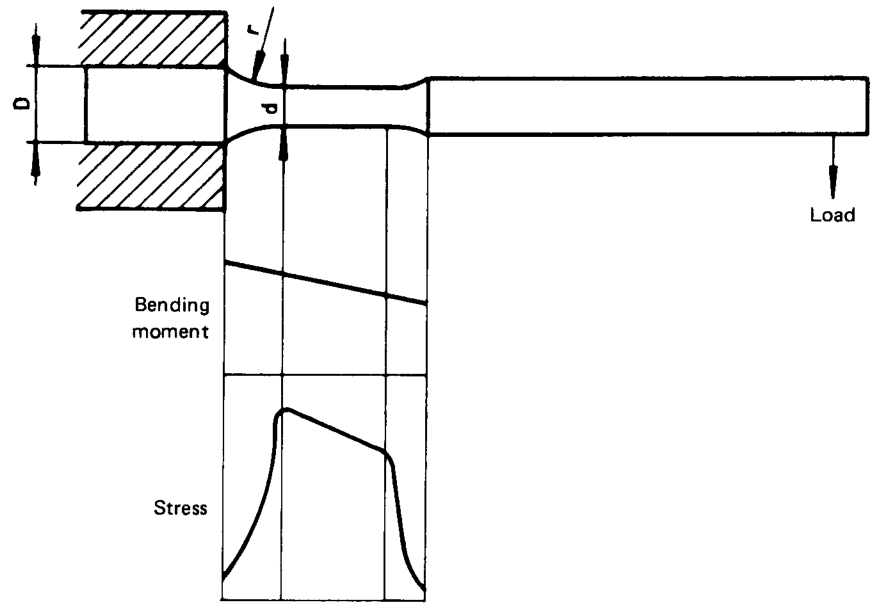

FIG. 1 – **Parallel test piece – single-point loading**

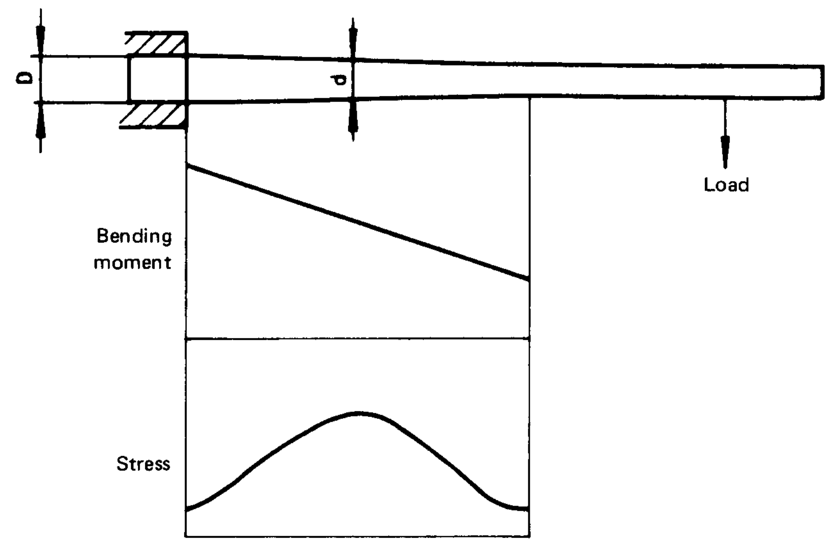

FIG. 2 – **Tapered test piece – single-point loading**

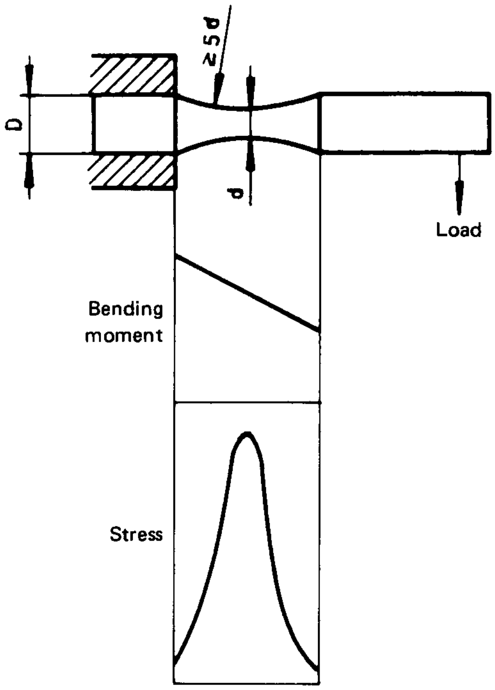

FIG. 3 – **Toroidal test piece – single-point loading**

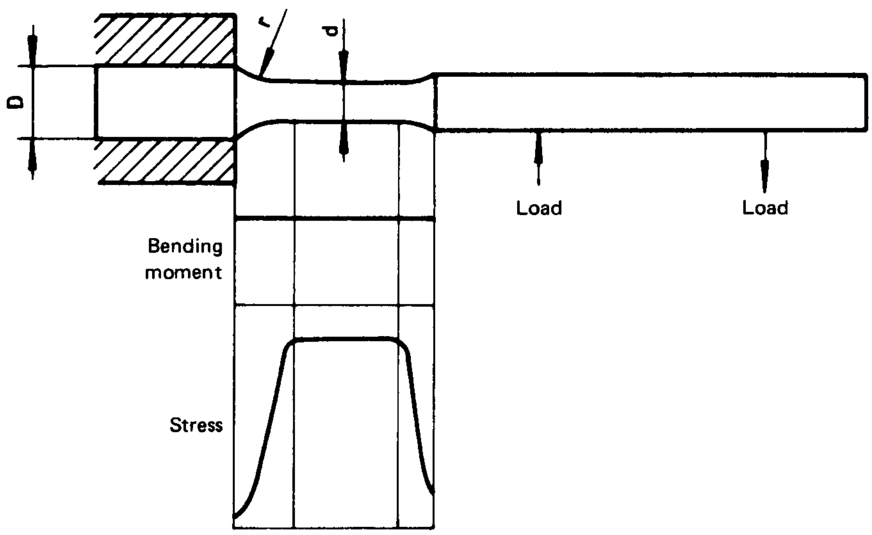

FIG. 4 – **Parallel test piece – two-point loading**

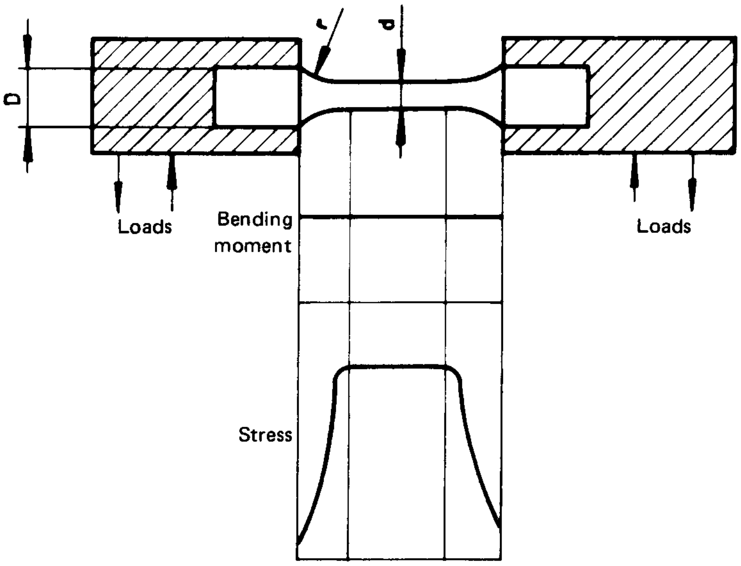

FIG. 5 – **Parallel test piece – four-point loading**

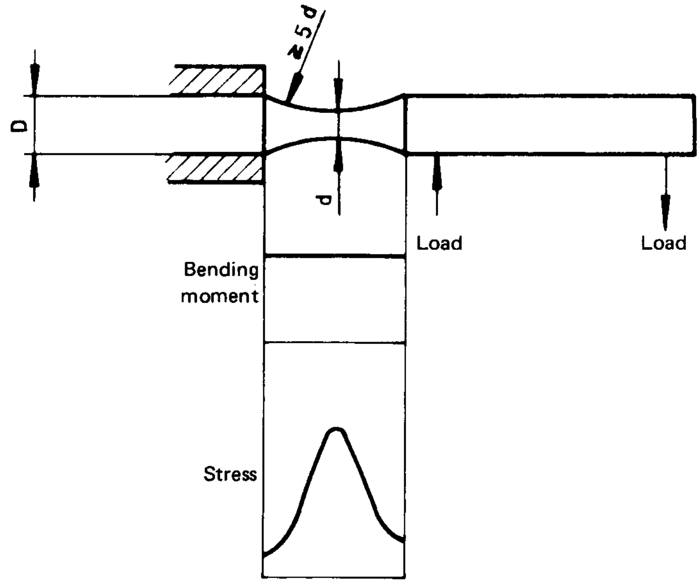

FIG. 6 – **Toroidal test piece – two-point loading**